Enhancing Parent-Child Language Interaction in the Pre-School Years

Topping, Keith

Published in:
Promoting Academic Talk in Schools

Publication date:
2018

Document Version
Peer reviewed version

Keith James Topping

Enhancing Parent-Child Language Interaction in the Preschool Years

In Gillies, R. (Ed.), Promoting effective talk in schools.
London & New York: Routledge.

Language interaction between parents and *pre-school* infants and children is extremely important, as children's brains are developing at a speed they will never approach again. High quality interaction enhances child language development, which in turn predicts better performance later in school and employment. Parents commonly over-estimate how much they talk with their pre-school children, so some form of structured feedback is needed to help them to see the possibilities. The **L**anguage **En**vironment **A**nalysis (LENA) system automatically analyses large amounts of parent-child language interaction and yields quantitative feedback which can cause parents to enhance their interactions. This chapter focuses on how parents can be encouraged to engage in high quality language interaction with their pre-school children, in relation to adult word count but particularly in relation to conversational turns. Parents below average in language interaction showed significant and sustained gains. The chapter looks at studies in the US but also in China and Korea, examining universal imperatives irrespective of the actual language involved. LENA is now being introduced into schools, although detailed evaluation is awaited.

Keywords: language, preschool children, **L**anguage **En**vironment **A**nalysis (LENA), automatic analysis, feedback, parents, schools

Corresponding author: Professor Keith Topping, School of Education, University of Dundee, Dundee DD1 4HN, United Kingdom. Orcid *0000-0002-0589-6796.* Tel: +44 (0)7854 833556. Email: k.j.topping@dundee.ac.uk.

Keith Topping is Professor of Educational and Social Research in the School of Education at the University of Dundee in Scotland. He has written approaching 400 research publications and been translated into 12 languages. He has extensive experience working with teachers, children and parents in a great many school districts, as well as with government and non-governmental organizations, in the U.K., U.S. and many other countries. Further details are at https://www.dundee.ac.uk/esw/staff/details/toppingkeith-j-.php#tab-bio.

Funding Source: These studies were funded by the LENA Research Foundation, a non-profit 501(c)3 public charity. No numbers.

Financial Disclosure: The author has no relevant financial relationships to disclose.

Conflict of Interest: The author has no conflicts of interest relevant to this article to disclose.

Acknowledgements: Thanks are due to Jill Gilkerson and Jeffrey Richards of the LENA Foundation, who played a large role in supporting the projects reported here. The authors also acknowledge Terry and Judi Paul, Founders of the LENA Research Foundation, for their wisdom and philanthropy, without which none of this work would have been possible.

Enhancing Parent-Child Language Interaction in the Preschool Years

This chapter focuses on how parents can be encouraged to engage in high quality language interaction with their pre-school children, in relation to adult word count but particularly in relation to conversational turns. Some parents may drown their children in words but not have attentive reciprocal conversations with them. Others may issue directive commands which do not invite a verbal response - another problem. The LENA system offers computer-assisted analysis of large amounts of parent-child language interaction, which yields quantitative feedback which can cause parents to enhance their interactions. But why is language interaction between parents and pre-school children in the early years important?

Early Language Development and Later Performance

We know that enhanced language abilities in very young children sustain over time and are important determinants of success in school and later in employment. Neural networks for language acquisition are fully formed before birth and babies can begin to learn language in utero by 35 weeks gestation (Zauche, Mahoney, Thul, Zauche, Weldon, & Stapel-Wax, 2017). Children's brains are developing at a speed they will never approach again. Early childhood is thus a time of immense opportunity for establishing the neural circuitry necessary for higher learning.

Feinstein and Duckworth (2006) studied 17,196 children in the UK, concluding that pre-school development in vocabulary was highly predictive of subsequent achievement, showing a strong relationship with both educational success and income at age 30. In a 29-year follow-up of 6941 men and women in the British Cohort Study, Schoon, Rush, and Law (2010a, 2010b) found

not only did a direct assessment of receptive language skills at age five predict the participant's level of literacy in adulthood at age 34 (even after adjustment for socio-economic status); it also predicted whether they would have subsequent social or emotional problems. Save the Children (2015) investigated the relationship between children's language skills at age five and their attainment in English and Math at ages seven and 11. Children struggling with language at age five were much more likely to have a poor standard in English at the end of primary school – and this was even more pronounced for mathematics, even when socio-economic status was taken into account.

Even very young pre-verbal children can respond to adult stimulation (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Rowe, 2008). The properties of adult caregiver language are strongly associated with subsequent child language development. For example, the rate at which adults talk to children (Huttenlocher et al., 1991) and the degree of engagement of children in conversational turns with parents (Tamis-LeMonda, Bornstein, & Baumwell, 2001; Authorname1, 2013) are all strongly linked to subsequent child vocabulary size. Conversely, deprivation in quality or quantity of language input leads to delayed language acquisition, lowered intelligence quotient, and reduced subsequent academic achievement (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Topping, Zeedyk, & Dekhinet, 2013).

However, early attempts to study parent-child language were bedevilled by the difficulty of obtaining good quality assessments of the interactions. Transcription of interactions took a long time, and analysis of the transcriptions even longer, as the Hart and Risley (1995) study testifies (it took four years to transcribe and code their 1,200 hours of audio data) – albeit that the findings that early parent-child language interactions made an enormous difference to children's language performance were startling. Could a system for automated analysis of language

interactions be developed and how reliable would it be compared to human transcription? This led to the development of the LENA system.

What is the LENA System?

The LENA (**L**anguage **EN**vironment **A**nalysis) system (Ford, Baer, Xu, Yapanel, & Gray, 2008; Gilkerson & Richards, 2008) uses automated assessment of whole-day samples of parent-child language with very young children. The baby or child is fitted with a digital audio recorder and then the full recording is sent out for analysis by computer. LENA does not attempt to uniquely identify individual sounds or words, but automatically categorizes interactions according to whether they indicate an adult speaking (Adult Word Count - AWC), a child vocalizing (Child Vocalization Count - CVC) or a conversational turn taking place (Conversational Turn - CT) (AWC can be divided into male and female, and CVC into target child and another child, as well as the identification of other unwanted noises such as television and digestive noises). Feedback is then available for professionals and parents, which enables parents to moderate their interactive behaviour accordingly.

Parents attach a small digital recorder to the child for one day per week. The recorder is kept in a front central chest pocket in special infant clothing, designed to optimize microphone placement and minimize clothing friction noise. The day is chosen by the parents and will typically be a day when at least one parent is available to interact with the child for a period of time, although this is not necessary and LENA will interpret all adult interactions with the child. Recording covers a maximum of 16 hours (optimally within a 6–10 foot radius at 16 kHz), far longer than human transcription could handle. There are of course issues concerning the validity

of data collected by such non-random sampling, but this does not affect the use of LENA as an intervention device. Data are collected in children's natural environments: homes, parks, playgrounds, and anywhere else children use or hear language.

The device records all linguistic interaction with parents, other adults, siblings, television, and so. Recordings are then processed by a digital sound analyser that uses algorithms to parse out the child's speech-related vocalizations and exposure to adult speech, the speech of other children, overlapping talk, silence, general noise, and television. LENA algorithms were developed and normed on a large database of speech samples collected from more than 300 AE speaking families (for a more complete explanation, see Richards, Xu, Gilkerson, Yapanel, Gray & Paul, 2017). The algorithms also enable the discarding of crying or vegetative sounds (e.g., from respiratory or digestive systems). LENA partitions utterances into words or word-like sounds, each separated by a momentary silence. For adults the sum of these is AWC. For target children the sum of such vocalizations is CVC. Speech-related vocalization covers anything from babbling and quasi-vowels from preverbal children to fully articulated verbalizations in words and sentences from older children. A CT between parent and child is an adult word followed by a child vocalization within five seconds. These are quantitative indices and LENA does not attempt to analyse the quality of the linguistic interaction.

Feedback reports are then delivered to parents by computer (usually on a weekly basis with one recording day's results) (see LENA Daily Feedback Report in Figure 1), but usually interpreted in the context of face to face meetings with professionals. Feedback identifies the rate of the three main variables at different points throughout the day, indicating the strengths and weaknesses in all three at different times. This enables parents to see **when** they might enhance their interaction with their child (by looking at episodes when they and the child are together but

not interacting) and (more importantly) **how** in terms of the balance between indices – since for example a high AWC with a low CT would not indicate effective interaction. Increased AWC is a positive indicator of parent-child interaction only when CT or CVC or both are also increased. If either CT or CVC or both are not increased then increased AWC is neutral – i.e. it is not having any effect on the child who is merely being drenched in adult words, to which it is not paying any attention. For the parent it represents a misdirection of effort. However, we have not established a single optimum ratio of AWC to CT empirically - different studies show different ratios.

INSERT FIGURE 1 “LENA Daily Feedback Report” ABOUT HERE

Discussion about reports occurs in group meetings, home visits, telephone calls or online messaging boards. The professional always talks about the balance between AWC and CVC and the importance of CT at all times of day. Accepting there is an issue about the typicality of the day of recording, the professional also discusses how other non-recording days might have been different and what the implications might be. Professionals make recommendations regarding useful activities which help increase the quantity of parent-child language interaction, such as nursery rhymes and reading (even with very young children). However, interaction between parents is also very important in terms of support. In some locations, the professionals also indicated the average group scores for AWC, CVC and CT, so parents could compare their own scores to this average. This was not done in the US, however.

Thus a relatively lower level of precision in an automated system can be compensated for by the system’s ability to process much larger quantities of data more efficiently than a human could. The relationship between AWC and CVC has been observed in preterm children (Caskey, Stephens, Tucker, & Vohr, 2011). Moreover, AWC, CVC and CT have been shown to be useful

in distinguishing the language environments of special needs populations, including young children with language delays (Oller, et al., 2010), being hard of hearing (Wiggin, Gabbard, Thompson, Goberis, & Yoshinaga-Itano, 2012), or diagnosed with an autism spectrum disorder (Dykstra, Sabatos-DeVito, Irvin, Boyd, Hume, & Odom, 2013).

LENA as an Assessment System: Previous Research

Clearly, if you wished to uniquely identify individual items of vocabulary, LENA would not help you. You would be forced to rely on human transcription (and consequently have a much smaller sample of participants), as untrained speech recognition is not yet sophisticated enough to permit automatic identification of individual utterances, especially for young children. However, if you wished to assess the *character* of the interaction between parent and child, LENA could help you, provided AWC, CVC and CT were assessed sufficiently reliably. Importantly, you could do this much faster and with much lower labour costs than if you were relying on human transcription.

Xu, Yapanel and Gray (2009) compared segments identified by professional human transcribers to segments identified by LENA in 70 audio files. Adult words had a human-computer correspondence of 82%, child vocalizations 76%, and TV 71% and other noises 76%. The reliability correlation for AWC was .92. Gilkerson, Coulter and Richards (2008) investigated inter-rater reliability between eight different human transcribers for the same files. For adult speech, reliability was .87-.89 and for child vocalization .90-.93.

The next question was how LENA might perform in languages other than American English (AE), while still using the American English norms. Weisleder & Fernald (2013) used LENA to evaluate the home language environments of low socioeconomic status Spanish-

speaking families living around Palo Alto, California. Transcriptions of ten 60-min recording samples showed a correlation of .80 between transcriber word counts and LENA Adult Word Count, indicating that LENA could reliably estimate the frequency of adult word use in Spanish language environments.

Canault, Le Normand, Foudil, Loundon, and Thai-Van (2016) investigated the reliability of LENA in French. Eighteen native French-speaking children were divided into six age groups ranging from 3 to 48 months old and recorded for three days per week. Six 10-minute sections of recordings (a total of 324 samples) were transcribed and aligned to LENA AWC and CVC. AWC and CVC estimates were reasonably reliable (r = .64 and .71, respectively). Spanish and French are of course Romance languages (originating from Latin); not so different from English.

Attention then turned to the use of LENA with bilingual children (in these cases in English and Spanish). Wood, Diehm and Callender (2016) compared LENA and human transcription for 42 bilingual and 39 monolingual preschool children from migrant low-socioeconomic-status backgrounds. CVCs and CTs were lower for bilingual than monolingual children, but were not strongly related to mean length of utterance for either group. Marchman, Martínez, Hurtado, Grüter and Fernald (2017) compared parent estimates to LENA recordings in a study of 18 3-year-old bilinguals. LENA AWC was consistently predictive of children's processing speed and standardized test performance.

We now also have some preliminary evidence that LENA measures directly predict outcomes at 10-year follow-up (Gilkerson & Richards, 2017). Children (n=146) (balanced by age and socio-economic status) who engaged in LENA recording when aged 2-48 months were re-assessed when aged 9-13 years. For children aged 18-24 months at initial intervention, initial CTs correlated at 0.44 with Wechsler Full Scale IQ and at 0.57 with Verbal Comprehension.

Initial AWC correlated at 0.37 and 0.42 respectively. Peabody Picture Vocabulary Tests correlated at 0.43 for CT and .33 for AWC. The other age groups' initial CTs or AWCs were not significantly correlated. So the age 18-24 months seemed crucial for language development.

Thus LENA AWC, CVC and CT seem relatively reliable in relation to human transcription, both in AE and in Spanish and French, and in Spanish and English simultaneously with bilingual children. Additionally, LENA measures at 18-24months have been found to predict global performance at 10-year follow-up.

LENA as an Intervention System: Previous Research

There have been studies of the use of LENA specifically in an intervention context in the US. Suskind and colleagues reported significant elevations in talk and interaction using LENA feedback coupled with caregiver coaching in home visiting programs (Suskind, et al., 2013). Suskind, et al. (2016) followed this up with a study of 23 low socio-economic status (SES) parents and their children (aged 18–36 months), although there was a good deal of attrition (as is typical low-SES populations). Twelve experimental and 11 control children allocated randomly to condition received eight weekly home visits. For the experimental group these were hour-long, focused on parent–child interactions to promote language development and included live and video modelling by the visitor and discussion of video taken by the parent of themselves interacting with their child. For the control group they were much shorter (10 minutes) and focused on nutrition.

In the experimental group parent knowledge of language development increased significantly 1 week and 4 months after the intervention, but not in the control group. For the

experimental group, adult word counts (Cohen's δ = .34), conversational turn counts (δ = .66), and child vocalization counts (δ = .43) increased significantly during the intervention. At post-intervention the scores were still somewhat elevated, but not statistically significantly. Thus the intervention showed effects, but not all of these were significantly maintained post-intervention (although of course small sample size was an issue and effect sizes should perhaps have been used).

However, all these interventions were conducted in the USA, and interventions outside that context were unheard of. There are currently a considerable number of such interventions progressing in the US, although not reported on as yet. The reader may wonder whether there are studies which directly compare information/coaching to families about language development with those strategies plus LENA feedback, but currently there is no such study. Another issue is whether LENA could replace some of such information/coaching and thereby yield greater cost-effectiveness.

New Research in the US

Three new studies are worthy of note. One showed that parents commonly over-estimate how much they talk with their pre-school children, so some form of structured feedback is needed to help them to see the problem (Richards, Gilkerson, Xu, & Topping, 2017). These authors investigated whether parent perceptions of their own and their child's levels of talkativeness were related to objective measures from the LENA system. Parents of 258 children aged 7-60 months completed a questionnaire on which they rated how much they and their child talked. Six months previously, they had recorded in their home language environment using the LENA

System. Compared with LENA measures, parents tended to overestimate how much they talked to their child, but were somewhat closer when estimating their child's talkativeness. Results were similar for a smaller sample with concurrent recordings. This thus indicated that calibration of talk volubility is challenging without a reference standard. An important implication was that parents who overestimate how much they talk to their child may also underestimate what they could do to enhance their child's home language environment.

Another study looked at reading as a means to accelerate language, even with very young children. An important factor is the amount of time spent reading to the child. Even with children less than one year old, the elaborated language of reading enhances child language development Gilkerson, Richards, & Topping (2017). This study had 98 families return reading activity logs for a day coinciding with LENA automatic language analysis yielding AWC, CT and CVC. Thirty-six reported reading with their child aged 26–61 months. Reading periods yielded much higher AWC and CT than non-reading periods, indicating a greater degree of parent–child language engagement and interaction during reading periods. AWC and CT were high during reading for both high and low education level mothers.

A third explored the possibilities of intervening with parents by online means (Gilkerson, Richards, Xu, & Topping, 2017). Seventy-two parents of typically developing children aged 9 to 21 months were assigned to immediate- or delayed-treatment (control) conditions. During the treatment phase, parents completed 10 recordings over a 3-month period while engaging in a web-based program supporting interpretation of LENA feedback reports and strategies for increasing talk and interaction. Parents completed additional recordings and language assessments over a 9-month follow-up phase. Overall analysis found no differences in language behaviours between groups. However, parents who started from below average ratings on

automated language measures demonstrated significant post-intervention increases which sustained longitudinally. Results thus suggested that an online intervention approach can help some parents increase talk and interaction in the home.

New Research beyond the US

So LENA as an assessment system seems reliable in AE and Romance languages, but it had never been tried out in non-Romance languages. LENA as an intervention system seemed effective but had only been tried out in the United States, and had never been tried out in other countries. So researchers set out to investigate its use as an assessment system and as an intervention system in very different countries and languages, namely China and Korea.

Why test LENA in China and Korea? Terry Paul, the originator of LENA, felt that parents in these countries had a high motivation for their children to succeed. He wanted to test out LENA in an environment apparently highly suited for success in this regard, but where it was unknown whether LENA in its US version would work with Asian languages. Once this was established, intervention in these countries could be attempted. Thus there were two assessment studies and two intervention studies.

China Assessment: Volunteer parents of 22 children aged 3–23 months (12 female, 10 male) were recruited in Shanghai using flyers, emails and word of mouth from two sites: a hospital and a learning centre. This was an experimental-only self-selected group. All were Han Chinese, aged 20-30 and of relatively high socioeconomic status and college-educated. All households had two parents present and at least one other person, either a grandparent or a nanny. While

parents tended to use Mandarin, grandparents tended to use Shanghai dialect. Nannies or grandparents typically looked after the child while both parents were out at work.

For baseline, families recorded three times over two weeks. One recording was chosen randomly from these and three 5-minute audio samples extracted from morning, afternoon and evening. A native speaker listened to 15 min of randomly selected audio samples per family to label speaker regions and provide Chinese character and Shanghai Dialect and Mandarin (SDM) word counts for adult speakers. LENA segment labelling and counts were compared with rater-based values. The reliability and validity of LENA segmentation and AWC and CT estimates for SDM-speaking families were compared with human rater values in terms of descriptive statistics, percentage agreement and correlation.

To evaluate AWC accuracy, we compared both the rater's Chinese character and SDM word counts derived from pinyin with AWC. Chinese character counts were nearly perfectly correlated with pinyin word counts, $r(20) > .99$, $p < .001$. Chinese characters correlated with AWC at .72 and SDM words correlated at .73. Transcribed turns correlated with CT at .69, and when three outliers were excluded at .87. This suggested that validation efforts not requiring word counts could use the less labour intensive character counts. SDM word counts were not significantly different from AWC. LENA demonstrated good effectiveness in identifying adult talk and child vocalization (80% consensus between LENA and human transcription. Precision was strong for adults but less so for children. LENA AWC correlated strongly with both Chinese characters and SDM word counts. LENA CT counts correlated similarly with rater-based counts after the exclusion of three unusual samples. Performance related to some degree to child age (Gilkerson, Zhang, Xu, Richards, Xu, Jiang, Harnsberger, & Topping, 2015).

Korea Assessment: We had two sources of data to investigate the relationship of LENA counts to human transcripts in Korean language: 27 transcripts (about 10 minutes each) from children aged 3–15 months in home environments and 36 transcripts from children aged 11–22 months in a clinic (in a 10-minute book reading and play context). The 63 human transcripts were compared to LENA recordings for the same families. Human counts and LENA counts (AWC and CT) were analysed in terms of descriptive statistics, percentage agreement and correlation between scores.

Overall, human AWC counts were significantly correlated with LENA AWC counts ($r = .72$, $p < .001$). However, human CT counts were initially not significantly correlated with LENA CT counts ($r = –.03$, $p > .05$). When we excluded the data of five babies containing abundant overlaps or whining noises, there were significant correlations between human and LENA CT counts ($r = .67$, $p = .001$) (overlaps are human vocalizations confused with other sound sources). When a child is very young or has frequent whining sounds and/or overlapped speech, LENA CT counts might need to be interpreted cautiously (and here the importance of the professional's role is considerable). The data for 10 babies (28%) were assessed by two transcribers for inter-rater reliability. Agreement rate was 98.5% for AWC and 95% for CT. Overall it seemed that LENA AWC and CT counts could be applied to the Korean language context (Pae, Yoon, Seol, Gilkerson, Richards, Ma, & Topping, 2016).

China Intervention: Volunteer families of 22 children participated (as in the Assessment study reported above), recording weekly for eight months. Parents completed simultaneous logs which indicated the people present during each recording hour. The profiles during the day (when the

parents were out at work) evidenced that the adult then talking used similar numbers of words and turns with similar child vocalizations as when the child was with parents.

All 22 families indicated both parents and grandparents were present during the majority of bi-weekly recordings. Fourteen out of 22 reported parents' presence during all recordings, five reported parents for 50-99%, and three reported parents for less than 50% of recordings. Fifteen out of 22 reported grandparents present during all recordings, six reported grandparents for 75-99% of recordings, and one reported grandparents present for only 13% of recordings. Nannies were reported present during recordings by only 8/22 families, half of whom reported their presence for more than half of their recordings. Thus grandparents were present at least twice as often as nannies during recordings. Feedback workshops of 90 min delivered by native speakers were made available monthly at local centres. Most parents attended. Analysis was by descriptive statistics, Pearson correlations and paired-samples t tests.

Quantitative measures of AWC and CT were collected at bi-weekly intervals over an eight-month period. These Chinese families showed much higher spontaneous rates at baseline than had been the case in prior studies with US families. Feedback reports to parents included individual family plus group counts. Impact was assessed by changes in quantitative measures and pre-post child language assessments administered by speech-language pathologists (Bayley Scales of Infant Development (BSID), MacArthur-Bates Communicative Development Inventories (MCDI), and Minnesota Child Development Inventory (CDI). Overall families increased word and turn counts significantly for the first three months, then regressed to baseline levels. However, parents below median at baseline maintained significant word increases to study conclusion. Adult word and turn counts predicted BSID and CDI but not MCDI language

development measures. There were no significant differences between families with grandparents and nannies present and those with only parents present.

We compared the performance of families above and below average in AWC and CT. There were 11 children in each group, with no significant difference in age between them. At baseline there was no significant difference between the groups in AWC $t(20) = 0.13$, $p=.90$ or CT $t(20) = 0.34$, $p=.74$. In terms of final outcome, however, it was clear that effects were largely accounted for by families in the lower half of the sample, who raised their scores 50% and 51% for AWC and CT respectively in the first month. Parent reports of book reading increased more than 50% (Zhang, Xu, Jiang, Gilkerson, Xu, Richards, Harnsberger, & Topping, 2015). Quantitative feedback with parent training thus had a significant impact on parent-child interactions in Shanghai families for below-median parents.

Korea Intervention: This study was a quasi-experimental intervention/control (wait group) design. Participants were volunteer parents of 99 typically-developing children aged 4–16 months, recruited from a paediatric clinic, a church, a workplace parent group, two baby centres, and three day care centres. There were 45 boys (45%) and 54 girls (55%). Most families were middle class, 74% were college graduates and 20% had a master's and/or doctoral degree. Almost half the mothers (43%) had a full-time job. Fourteen of the children (14%) attended day care centres. The sample was then randomly divided into experimental and control (wait-list) groups. Each child in the experimental group was matched with a child of similar age in the control group, since language from a 5-month-old is very different to that of a 30-month-old, and each recording was thereby controlled for the child's age at baseline. At baseline groups were not significantly different.

The experimental group received a single workshop the second month after starting. In the workshop, the group viewed six short (2-minute) video clips, participated in discussions of parental experiences, and received advice about enhancing the home language environment. Individualized LENA reports were explained in detail (see Figure 1). Given their own individual AWC and CT for each recording, parents were encouraged to set an individual goal to do better at next recording. Parents could also see how their and their child's performance compared to the US norms for LENA in terms of percentiles, and consequently whether they and their child were below or above average and by how much. The LENA feedback was delivered to the parent's home computers on a weekly basis. Every month the experimental group families were also telephoned by a research assistant in order to check whether they had any technical problems and to give encouragement. At the sixth month, the experimental participants were given five storybooks for babies and an online book-reading guide. The control group received no feedback, support, workshops, or storybooks. The control group recorded at the third month and at the end of the 6-month period to add to their baseline recording.

Chi-squared was used to test for significance with nominal variables. Two-way repeated-measures analyses of variance were conducted to evaluate groups' differences in LENA measures at baseline, 3 months, and 6 months. Post hoc tests were conducted where the analysis of variance yielded significant results, either independent or paired *t*-tests.

There was no significant difference between the above/below AWC/CT average talk groups at baseline. For the above average and below average groups' AWC and CT there was a significant interaction between time and above/below average performance. For the below average talk group, AWCs in months 3 and 6 were significantly higher than the baseline scores. For the above average talk group, AWC in month 3 was lower than the baseline score (but not

significantly), while AWC in month 6 was significantly lower than baseline scores. For CT in the below average group, in both months 3 and 6 scores were significantly higher than baseline. For the above average group, CT in both months 3 and 6 was slightly higher than the baseline score but not significantly. This indicated that feedback worked better for the below average group than the above average group. Korean parents whose linguistic environment was below average adapted their communicative interaction in response to linguistic feedback (Pae, Yoon, Seol, Gilkerson, Richards, Ma, & Topping, 2016).

In all four studies implementation integrity was principally measured by the LENA system itself.

Future Developments

For the future, studies with socio-economically disadvantaged parents who are more likely to have children with language delay are under way, but the results are yet to be published. In this case, the parents may be more motivated but sustaining intervention over long periods may be a challenge.

However, the transition from home to school raises issues for sustaining effective language intervention begun in the home. Studies are ongoing investigating the utility of the LENA Grow program to enhance adult-child dialogue in childcare settings and early years' classrooms, where many children spend up to 60% of their waking hours. LENA Grow is a program for childcare providers incorporating LENA technology with face to face training in interpreting LENA data and providing additional language stimulation which is targeted especially on enhancing CTs, together with shared reading to maximize language interaction

intensity. It is expanding to reach more sites, and in 2018 is heading for the 100 classrooms benchmark. LENA in a group setting can be used with the recorder located on the adult (with consequent economies of scale). Alternatively three or more target children in the class representing children of different abilities can be recorded, but this generates more analysis to be interpreted for the adult. Of course LENA can also be used with individual children if that is possible.

The first pilot evaluation of LENA Grow is now available (Teaching Strategies, 2017). Two initial training sessions were provided for teachers. A total of 12 children in two classrooms were involved for four months. All children wore the recorder. Curriculum materials provided included teaching cards, longer publications, brief activities, conversation cards and learning games. Teachers met with a coach every two weeks and interim support was by email newsletters and phone calls. In terms of results, there were differences between classrooms. Classroom 2 (which had the oldest children, 1-2 years of age) had the largest gains, with an overall increase of 161 adult words per hour from baseline to the average of the last three recordings, and an overall increase of 10 conversational turns per hour from baseline to the average of the last three recordings. Classroom 1 showed an overall gain of 73 words per hour from baseline, but did not show any change in conversational turns. However, Classroom 1 had much higher baseline levels of interaction.

There are also likely to be opportunities to introduce LENA at school level. At least in schools there are teachers, of relatively easy access, and the critical mass of many schools gives a platform for developing projects at some scale. Dykstra, et al. (2013) used LENA in classrooms with 40 children with autism. Most of the LENA measures were correlated with other traditional measures and had implications for use in an intervention. Turning to mixed-ability children,

Wang, Miller and Cortina (2013) used LENA with mathematics teachers in training, and found the feedback helped them limit the amount of teacher talk and increase the amount of student talk. This was effective in increasing the amount of teacher-student discussion. Wang, Pan, Miller and Cortina (2014) then described using LENA with practicing teachers to help enhance the quality of classroom discourse in teacher lecturing, whole class discussion and student group work. In this application, the teacher wore the recording device. Again, the system was effective in enhancing classroom discourse.

In addition, it appears that LENA can be used with many languages, including languages quite unlike American English, so it seems likely to be used in many more countries.

Conclusion

Thus we found that LENA as an assessment tool was reliable not only in Romance languages but also in Mandarin, Shanghai Dialect and Korean languages. We also found that LENA as an intervention tool had a marked effect on below-median families, although not on above-median families. In relation to the previous literature, the first finding was completely novel, and the second novel for these countries.

One feature of both the Chinese and the Korean study was that they showed seasonal effects. Both in Shanghai and in the north of South Korea, the heat during the summer is quite intense. This led to some parents being disinclined to make their children wear the clothing necessary to hold the recorder, so some recordings were lost. Thus studies in countries with hot summers should attempt data gathering during the cooler months of the year if possible. The Asian studies also engaged participants who were largely urban and middle-class. More studies are needed in both countries with participants who are more rural and working-class.

Given that the Asian studies were generally with middle-class parents, they might have been more sophisticated about technology. The use of a system that was reliant on technology and required some use of computer skills might have motivated these parents. How well the studies would have worked with parents in rural or disadvantaged environments is another question.

Giving feedback to all parents about their position in relation to group averages was intended to motivate the parents by capitalizing on competition, and this seemed to be successful for below-average parents (although we note there was some evidence of above-average parents declining in scores). Of course, the study populations were already of average or above socio-economic status, so we do not know if this would also be true with lower socio-economic groups – or indeed whether the same competitive element would be present in the West. Further carefully controlled studies are needed here.

The LENA system does give grandparents and nannies a structured means to enhance their language interaction with the children they care for irrespective of language. However, our evidence suggested that these Asian care-givers already had higher rates of interaction than was typical in the US, so not much value might be added (although in rural disadvantaged communities this might be less so).

Intervention could be attempted in many other countries. The issue of cost-effectiveness is relevant here, especially in developing countries. LENA has four components which cost money: the recorder, the computer analysis and feedback information, the initial training or participants, and subsequent monitoring and coaching. Usually the first two are provided by the LENA Foundation (although LENA does provide training for professionals face-to-face in the USA and via webinars for professionals in other countries) and the third and fourth by the local

community, through whatever professionals seem relevant and interested. In schools, the cost per class is greatly reduced if the teacher wears the recorder. LENA is a non-profit foundation, so prices are kept to a minimum.

The LENA system thus presents exciting possibilities for exploring and enhancing the language interaction of very young children right through into school, both as an assessment system and as an intervention system. Enhanced early language leads to enhanced literacy and better performance in other subjects, which in turn leads to better employment prospects and better socio-emotional adjustment. Information about language development and LENA could be provided through parent information/support meetings in the community or in the school (irrespective of the age of the target child), leading into more structured intervention projects. LENA could be a good way to start home-school communication and provide a concrete practical method to support families.

References

Canault, M., Le Normand, M. T., Foudil, S., Loundon, N., & Thai-Van, H. (2016). Reliability of the Language ENvironment Analysis system (LENA™) in European French. *Behavior Research Methods, 48,* 1109-1124. doi: 10.3758/s13428-015-0634-8.

Caskey, M., Stephens, B., Tucker, R., & Vohr, B. (2011). Importance of parent talk on the development of preterm infant vocalizations. *Pediatrics*, *128*, 910–916.

Dykstra, J., Sabatos-DeVito, M. G., Irvin, D. W., Boyd, B. A., Hume, K. A., & Odom, S. L. (2013). Using the Language Environment Analysis (LENA) system in preschool classrooms with children with autism spectrum disorders. *Autism, 17,* 582–594. doi: 10.1177/1362361312446206

Feinstein, L., & Duckworth, K. (2006). *Development in the early years: Its importance for school performance and adult outcomes.* Wider Benefits of Learning research report no.20. London: Centre for Research on the Wider Benefits of Learning, Institute of Education.

Ford, M., Baer, C. T., Xu, D., Yapanel, U., & Gray, S. (2008). *The LENA Language Environment Analysis system: Audio specifications of the DLP-0121* (Report No. LTR-03-2). Boulder, CO: LENA Foundation.

Gilkerson, J., & Richards, J. A. (2008). *The LENA Foundation natural language study*. Boulder, CO: LENA Foundation.

Gilkerson, J., & Richards, J. A. (2017). *Early childhood language environments predict outcomes in adolescence: Results from a 10-year longitudinal study using automated analysis.* Poster at American Academy of Pediatrics National Conference, Chicago, IL, September 16-19.

Gilkerson, J., Coulter, K. K., & Richards, J. A. (2008). *Transcriptional analyses of the LENA natural language corpus*. Boulder, CO: LENA Foundation. (LTR-06-2).

https://3ezaxq2cvfwhsrafg2qaq2p4-wpengine.netdna-ssl.com/wp-content/uploads/2016/07/LTR-06-2_Transcription.pdf [Retrieved 14 Jan 2008]

Gilkerson, J., Richards, J. A., & Topping, K. J. (2017). The impact of book reading in the early years on parent-child language interaction. *Journal of Early Childhood Literacy*, *17*(1), 92–110. doi: 10.1177/1468798415608907.

Gilkerson, J., Richards, J. A., Xu, D., Topping, K. J. (2017). Online linguistic feedback to parents of young infants: A pilot study of viability and effects**.** *Journal of Early Intervention*, *39*(4), 281-298. DOI: 10.1177/1053815117718490.

Gilkerson. J., Zhang, Y., Xu, D., Richards, J. A., Xu, X., Jiang, F., Harnsberger, J., & Topping, K. J. (2015). Evaluating LENA system performance for Chinese: A pilot study in Shanghai. Journal of Speech, Language and Hearing Research, 58, 445–452. doi: 10.1044/2015_JSLHR-L-14-0014.

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Brookes.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology*, *27*, 236–248.

Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology, 45,* 337–374.

Marchman, V. A., Martínez, L. Z., Hurtado, N., Grüter, T., & Fernald, A. (2017). Caregiver talk to young Spanish-English bilinguals: Comparing direct observation and parent-report measures of dual-language exposure. *Developmental Science*, *20*(1), e12425. doi: 10.1111/desc.12425.

Oller, D. K., Niyogi, P., Gray, S., Richards, J. A., Gilkerson, J., Xu, D., . . . Warren, S. F. (2010). *Automated vocal analysis of naturalistic recordings from children with autism, language delay, and typical development*. Proceedings of the National Academy of Sciences, USA, 107, 13354–13359. doi:10.1073/pnas.1003882107

Pae, S., Yoon, H., Seol, A., Gilkerson, J., Richards, J. A., Ma, L., & Topping, K. J. (2016). Effects of feedback on parent-child language with infants and toddlers in Korea. *First Language, 36*(6), 549 –569. DOI: 10.1177/0142723716649273.

Richards, J. A., Gilkerson, J., Xu, D., & Topping, K. J. (2017). How much do parents think they talk to their child? *Journal of Early Intervention, 39*(3), 163-179. doi: 10.1177/1053815117714567.

Richards, J. A., Xu, D., Gilkerson, J., Yapanel, U., Gray, S., & Paul, T. (2017). Automated assessment of child vocalization development using LENA. *Journal of Speech, Language, and Hearing Research, 60*(7), 2047-2063. doi: 10.1044/2017_JSLHR-L-16-0157.

Rowe, M. L. (2008). Child-directed speech: Relation to socioeconomic status, knowledge of child development and child vocabulary skill. *Journal of Child Language, 35*, 185–205.

Save the Children (2015). *Ready to read: Closing the gap in early language skills so that every child in England can read well*. London: Save the Children.

Schoon, I., Parsons, S., Rush, R. & Law, J. (2010a) Childhood language problems and adult literacy: A twenty nine year follow-up study. *Pediatrics, 125*(3), 459-466.

Schoon, I., Parsons, S., Rush, R. & Law, J. (2010b) Children's language ability and psychosocial development: A 29 year follow-up study. *Pediatrics, 126*(1), 73 – 80.

Suskind, D. L., Leffel, K. R., Hernandez, M. W., Sapolich, S. G., Suskind, E., Kirkham, E., & Meehan, P. (2013). An exploratory study of "quantitative linguistic feedback": Effect of

LENA feedback on adult language production. *Communication Disorders Quarterly, 34*, 199–209. doi:10.1177/1525740112473146

Suskind, D. L., Leffel, K. R., Graf, E., Hernandez, M. W., Gunderson, E. A., Sapolich, S. G., . . . Levine, S. C. (2016). A parent-directed language intervention for children of low socioeconomic status: A randomized controlled pilot study. *Journal of Child Language, 43*, 366-406. doi: 10.1017/S0305000915000033.

Tamis-LeMonda, C. S., Bornstein, M. H., & Baumwell, L. (2001). Maternal responsiveness and children's achievement of language milestones. *Child Development, 72*, 748–767.

Teaching Strategies (2017). Using the Creative Curriculum with LENA Grow to increase language interactions in child care settings. Bethesda, MD: Teaching Strategies.

Topping, K. J., Dekhinet, R., & Zeedyk, S. (2011). Hindrances for parents in enhancing child language. *Educational Psychology Review, 23*, 413–455.

Topping, K. J., Dekhinet, R., & Zeedyk, S. (2013). Parent-infant interaction and children's language development. *Educational Psychology, 33*, 391–426.

Wang, Z., Miller, K., & Cortina, K. (2013). Using the LENA in teacher training: Promoting student involvement through automated feedback. *Unterrichtswissenschaft*, 41(4), 290-305.

Wang, Z. W., Pan, X. Y., Miller, K. F., & Cortina, K. S. (2014). Automatic classification of activities in classroom discourse. *Computers & Education, 78*, 115-123.

Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science, 24*, 2143–2152. doi:10.1177/0956797613488145.

Wiggin, M., Gabbard, S., Thompson, N., Goberis, D., & Yoshinaga-Itano, C. (2012). The school to home link: Summer preschool and parents. *Seminars in Speech and Language, 33*, 290–296.

Wood, C., Diehm, E. A., & Callender, M. F. (2016). An investigation of language environment analysis measures for Spanish-English bilingual preschoolers from migrant low-socioeconomic-status backgrounds. *Language, Speech, and Hearing Services in Schools, 47*(2), 123-134. doi: 10.1044/2015_LSHSS-14-0115

Xu, D. X., Yapanel, U., & Gray, S. (2009). *Reliability of the LENA Language Environment Analysis system in young children's natural language home environment* (Report No. LTR-05-2). Boulder, CO: LENA Foundation. https://3ezaxq2cvfwhsrafg2qaq2p4-wpengine.netdna-ssl.com/wp-content/uploads/2016/07/LTR-05-2_Reliability.pdf [Retrieved 14 Jan 2018]

Zauche, L. H., Mahoney, A. E. D., Thul, T. A., Zauche, M. S., Weldon, A. B., & Stapel-Wax, A. L. (2017). The power of language nutrition for children's brain development, health and future academic achievement. *Journal of Pediatric Health Care, 31*, 493-503. doi: 10.1016/j.pedhc.2017.01.007

Zhang. Y., Xu, X., Jiang, F., Gilkerson, J., Xu, D., Richards, J. A., Harnsberger, J., & Topping, K. J. (2015). Effects of quantitative linguistic feedback to caregivers of young infants: A pilot study in China. Communication Disorders Quarterly, 37(1), 16-24. doi: 10.1177/1525740115575771.